Alternate Wetting and Drying (AWD) Irrigation using cost-effective pani pipe method for smart water management system in rice cultivation

ABSTRACT

Large-scale front-line demonstrations on alternate wetting and drying (AWD) practices were conducted in the transplanted paddy growing regions of farmer's holdings of Tiruvannamalai district during the Kharif season of 2022-23 and 2023-24 under Tamil Nadu Irrigated Agriculture Modernization Project [TNIAMP - IV], Thurinjalar sub-basin, Tiruvannamalai district in Tamil Nadu. The productivity, economics, and water saving data in demonstrated plots were compared with the farmer's practices (Continuous flooding method). The extension gap, technology gap, and technology index were 12.0q ha^{-1}, 6.0 q ha^{-1}, and 8.57 percent, respectively. The higher gross return of Rs.1,27,991 ha^{-1}, higher net return of Rs.73,980 ha^{-1}, and Benefit-Cost ratio of 1.37 were observed in the demonstrated plot compared to farmers' practices of continuous flooding method. Higher yield and returns due to reduced cost of cultivation, higher grain yield, higher net returns, and higher water saving (24.7%) in the demo plot over the farmer's practices created greater awareness. They motivated the other farmers to adopt AWD practices in TN IAMP Phase IV Thurinjalar sub-basin farmers of Tiruvannamalai district.

Key words: Paddy, Field Water Tube, AWD, Pani pipe, Water Saving, Economics

INTRODUCTION

Rice (Oryza sativa L.) is a crucial staple crop globally, providing sustenance for a large portion of the world's population. It is a primary food source for the global population, with an average per capita consumption of more than 50 kilograms of rice annually (FAOSTAT, 2016). Globally, more than 478 million tons of milled rice were produced during 2014-15, with over 90% being directly used for human consumption (USDA, 2016). India's rice production overall accounts for 22.1 percent of the globe, with an output of 105 million tonnes, cultivated across an area of 44 million hectares (Anon, 2020). The availability of water, both on the surface and underground, has significantly decreased, presenting a challenge to rice production (Farooq *et al.*, 2009). The International Rice Research Institute, located in the Philippines, reported in 2009 that rice is one of the least water-use efficient crops. It takes approximately 5000 liters of water to produce 1 kg of unmilled rice. The traditional method of continuous flooding in water management for rice production makes water use less efficient. A significant amount of water can be saved and higher paddy yields can be achieved by using alternate wetting and drying (AWD) irrigation methods, resulting in an average 35% reduction in irrigation water consumption per hectare (Jagannath *et al*., 2013). While rice is crucial for global food security, traditional rice cultivation in flooded paddy fields requires more water than other cereal crops (Pimentel *et al*., 2004). The current threat of water scarcity is impacting an estimated 4 billion people worldwide (Mekonnen and Hoekstra, 2016), It is critical to develop agronomic practices with the potential to reduce water usage while maintaining or increasing yields to support a growing population. One irrigation management practice that has been demonstrated to reduce water usage in rice systems is called Alternate Wetting and Drying (AWD) (Linquist *et al*., 2014; Lampayan *et al*., 2015). Research has demonstrated that Alternate Wetting and Drying, an irrigation management practice, effectively reduces water usage in rice systems. Bouman and Tuong, 2001 reported that AWD reduces water inputs by 23% compared to continuously flooded rice systems. Recent projections suggest a looming water shortage in the next few decades. At this juncture, it is imperative to explore and implement an alternative system of rice cultivation that is water-efficient and minimizes the use of other input resources. Farmers can use Alternate Wetting and Drying (AWD) as a water-saving technique in rice cultivation. This method allows farmers to reduce irrigation water usage without compromising the yield. The introduction of irrigation practices in unsaturated soil conditions during the growing season can reduce water usage in rice cultivation without affecting yields. Tuong (2007) recorded the successful usage of field water tubes in the AWD irrigation methods to monitor the water depth and capable of indicating the right time of irrigation and saved water.

In Tiruvannamalai district, a staggering expanse of over 40,000 hectares of land is devoted to the cultivation of paddy during the kharif season, reflecting the significant agricultural activities in the region. The major problem identified was the indiscriminate use of irrigation water for paddy crops using continuous flooding and a lack of awareness about Alternate Wetting and Drying (AWD) irrigation methods through Pani Pipe. By considering the above-present demonstration was carried out to create awareness among transplanted paddy farmers of Tamil Nadu Irrigated Agriculture Modernization Project Phase-IV, Thurinjalar sub-basin in Tiruvannamalai district about the judicious use of irrigation water by using Pani Pipe. To effectively address the impact of climate change in rice production, it is essential to implement climate-smart practices that provide both mitigation and adaptation benefits.

MATERIALS AND METHODS

Demonstrations were carried out in irrigated lowlands using the alternate wetting and drying (AWD) irrigation method for two consecutive years during the kharif seasons of 2022-23 and 2023-24 under Tamil Nadu Irrigated Agriculture Modernization Project (TNIAMP) Phase-IV, Thurinjalar sub-basin by Agricultural College and Research Institute, Tamil Nadu Vazhavachanur, Tiruvannamalai. These demonstrations took place at the fields of farmers in the villages of Nariyapattu, Thalayampallam, Thatchampattu, Pavupattu, Parayampattu, Alikondapattu, Periyakallapadi, Pazhayanur, Pavithram, Kattampoondi, Navampattu, and Sakkarathamadai in the Thiruvannamalai district of Tamil Nadu, India. There were two treatments: T1 - Farmers practice (continued ponding of water at 5 cm depth) and T2 - AWD (irrigation water was applied when the water level dropped to about 5 cm below the surface of the soil). A practical method for safely implementing AWD involves using a 'field water tube' (also known as 'pani pipe') to monitor the water depth in the field. After irrigation, the water depth will gradually decrease. When the water level has dropped to about 5 cm below the surface of the soil, irrigation was applied to re-flood the field to a depth of about 5 cm. From one week after transplanting to week before flowering and during flowering the field was kept flooded, topping up to a depth of 5 cm as needed. After flowering, during grain filling and ripening, the water level was allowed to drop again to 5 cm below the soil surface before re-irrigation.

A field tube in flooded field: The field water tube in the field is 30 cm long with a diameter of 10-15 cm plastic pipe, making the water table easily visible and it is easy to remove soil inside. Perforate the tube with numerous holes at 2 cm intervals all around the tube to allow water to flow in and out easily. The tube was hammered into the soil so that 15 cm extends above the soil surface. The soil was removed from inside the tube to make the bottom of the tube visible. Alternate wetting and drying (AWD) were started a few weeks (1-2 weeks) after transplanting. When there were many weeds present, AWD was postponed for 2-3 weeks to help suppress the weeds with ponded water and improve the efficacy of herbicide. Fertilizer recommendations for flooded rice were followed. Nitrogen was applied to the dry soil just before irrigation. All the recommended agricultural practices were followed as per the Tamil Nadu Agricultural University guidelines.

The large-scale demonstration was conducted to study the technology gap between the potential yield and demonstrated yield, as well as the gap between demonstrated yield and yield under existing practice and technology index. The yield data were obtained from both the demonstration and farmers' practice using the random crop-cutting method. Qualitative data was converted to quantitative form and expressed as a percentage increase in yield. (Narasimha Rao *et al*., 2007). The data was further analyzed by using statistical tools. The technology gap, extension gap, and technological index were calculated as given below (Samui *et al*., 2000).

$$\text{Technology gap} = \text{Potential yield} - \text{Demonstrated yield}$$

$$\text{Extension gap} = \text{Demonstrated yield} - \text{Yield under existing practice}$$

$$\text{Technology index} = \frac{\text{Potential yield} - \text{Demonstrated yield}}{\text{Potential yield}} \times 100$$

RESULTS

Demonstrations of AWD irrigation method using cost-effective panipipe for rice cultivation in the Thurinjalar sub-basin, Tiruvannamali district under TNIAMP Phase IV at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Vazhavachanur, Tamil Nadu, India. The present study revealed that the grain yield, extension gap, technology gap, economic analysis and water-saving technology through the AWDI method using panipipe were demonstrated in farmers' holdings. The demonstration was conducted during 2021-22 and 2022-23 years and a total of 40 ha were demonstrated in the 40 locations of farmers holdings.

Yield analysis

The average grain yield under demonstrated plots was 63.3 and 64.7 q ha^{-1} with an average of 64.0 q ha^{-1} from the years 2021-22 and 2022-23, respectively when compared with farmers' practices of 51.7 and 52.4 q ha-1 with an average of 52.1 q ha^{-1} (Table 1).

Extension Gap

An extension gap between demonstrated technology and farmers' practices was calculated and on an average basis, the extension gap of 11.6 q ha^{-1} and 12.3 q ha-1 with an average of 12 q ha-^{1} was calculated (Table 1, Fig 1).

Technology Gap and Technology Index

The technology gap is calculated by subtracting the demonstrated plot yield from the potential yield of a paddy crop. In 2021-22, the technology gap was 6.7 q ha-1, and in 2022-23, it was 5.3 q ha-1, with an average technology gap of 6.0 q ha-1. The technology index was 9.57 percent during 2021-22 and in 2022-23, it was 7.57 percent with an average technology gap of 8.57 percent (Table 1, Fig. 1).

Cost-effective analysis

The technology demonstration revealed a higher gross return of Rs. 127991 ha-1 and a higher net return of Rs. 73980 ha-1, along with a higher benefit-cost ratio of 1.37 for two years compared to the farmers' practices. The farmers' practices had a higher gross return of Rs. 104128 ha-1, a higher net return of Rs. 51929 ha-1, and a benefit-cost ratio of 1.00 (Table 2).

Water management through AWD irrigation methods

The demonstrated technology observed less irrigation (20.5) and an average percent of water saving (24.7%) to complete the life cycle of paddy as compared to farmer's practices (25.5) (Table 2).

Farmer's assessment

The number of irrigations was very less, so water was saved using AWD through Pani Pipe technology, which will increase the production area, more tillers were produced, leading to a higher yield, with less pest and disease incidence due to AWD irrigation method. A Pani Pipe can be easily manufactured by farmers themselves using a simple method and this method reduces the cost per acre.

Discussion

Alternate wetting and drying irrigation management methods are used in irrigated lowland rice. In AWD irrigation method the rice field is allowed to dry for a few days before being flooded again. Hence the field is alternately flooded and left dry. Implementation of AWD irrigation management involves monitoring the depth of water in the field using a field water tube. AWD irrigation method reduces the amount of time in which rice fields are flooded and is assumed to reduce the production of methane by about 30-50%. Draining practice had a strong effect on methane emissions (Kazuyuki Yagi et al., 1996). The present study revealed that the grain yield, extension gap, technology gap, economic analysis, and water-saving technology through the AWDI method using pani pipe were demonstrated in farmers' holdings. The comparison between the grain yield of demonstration plots and farmer's practices revealed that the average yield of demonstrated plots was 23 percent higher than that of farmer's practices. This increase in yield in demonstrated plots may be attributed to the improved aeration in the root zone due to Alternate Wetting and Drying (AWD), resulting in a higher number of tillers per square meter and increased yield. The gap in extension and technology could be attributed to the adoption of AWD in demonstrated plots, leading to a higher grain yield than farmer's practices. Consequently, motivated by the extension gap, farmers were encouraged to adopt the AWD technique to reduce the gap and increase in the grain yield. The average technology index using the Pani Pipe method was 8.57 percent. A higher technology index indicates insufficiently proven technology being transferred to farmers and inadequate extension services for technology transfer. Proper management practices led to improved net returns, resulting in higher yields and ultimately higher returns. Similar results were reported by Raju *et al*., 2012, Santheepan and Ramanathan, 2016, Daniela et al. 2017, and Ayyadurai *et al*., 2024.

CONCLUSION

Improved water management practices for rice cultivation have the potential to significantly reduce agricultural greenhouse gas emissions, while also reducing freshwater use, increasing the profitability of rice farming, and maintaining yields. AWD irrigation is technically feasible, cost-effective, and beneficial for water saving and productivity in rice cultivation, leading scientists to work on refining the technology for broader.

References

Anonymous, 2020. Annual report on rice production.

Ayyadurai P, Kathiravan M, Muthukrishnan N, Raju M, Pazhanivelan S, 2024. Maximization of Productivity and Water Saving through Alternate Wetting and Drying Irrigation (AWDI) in Rice under Tamil Nadu Irrigated Agriculture Modernization Project (TN IAMP) Aliyar Sub Basin Farmers of Tamil Nadu, India. Asian Research Journal of Agriculture; 17(2):14-19.

Bouman BAM, Tuong TP. Field water management to save water and increase its productivity in irrigated lowland rice. Agric. Water Manage. 2001;49:11–30.

Daniela R Carrijo, Mark E Lundy, Bruce A Linquist. Rice yields and water use under alternate wetting and drying irrigation: A meta-analysis. Field Crop Research. 2017; 203(1):173-180.

Jagnnath P, Pullabhotla H, Uphoff N. Meta analysist evaluating water use: Water saving and water productivity in irrigated production of rice with SRI Vs. standard management methods. Taiwan Water Conservation. 2013;61:14-49.

Kazuyuki Yagi, Ken-ichi Kanda and Katsuyuki Minami, 1996. Effect of water management on methane emission from a Japanese rice paddy field: Automated methane monitoring. Global biogeochemical cycles.10 (2): 255-267.

Lampayan RM, Rejesus RM, Singleton GR, Bouman BAM. Adoption and economics of alternate wetting and drying water management for irrigated lowland rice. Field Crops Res. 2015;170:95–108.

Mekonnen MM, Hoekstra A. Four billion people facing severe water scarcity. Sci. Adv. 2016;2:1–6.

Narasimha Rao S, Satish P, Samuel G. Productivity improvement in soybean. Glycine max L. Merrill through technological interventions. J Oilseeds Res. 2007;24(2):271-273.

Pimentel D, Berger B, Filiberto D, et al. Water resources: Agricultural and environmental issues. Bioscience. 2004;54:909–918.

Raju R, Tripathi RS and Thimmappa K. Economics of zero tillage and conventional methods of riceand FAO. FAOSTAT Data; 2016. Available:http://faostat3. fao.org/browse/FB/CC/E [Accessed on 03 March 2016]

Samui SK, Mitra S, Roy DK, Mandal AK, Saha D. Evaluation of front line demonstration on groundnut. Journal of the Indian Society Coastal Agricultural Research. 2000;18(2):180-183.

Suresh Kulkarni. Innovative technologies for water saving in irrigated agriculture. International Journal of Water Resources and Arid Environments. 2011;1(3):226-231.

Tuong TP. Alternate wetting and drying irrigation (AWD): A technology for water saving in rice production. Paper presented at the Crop Cutting Ceremony, BADC Farm, Modhupur, Tangail; 2007

USDA. World rice production, consumption, and stocks. United States Department of Agriculture. Foreign Agricultural Service; 2016. Available:http:// apps.fas.usda.gov/psdonline/psdHome.asp x [Accessed on 03 March 2016]

Table 1. Productivity, Extension gap, Technology gap, and Technology index of paddy as grown under large-scale AWDI demonstration and an existing package of practices.

Year	Area (ha)	No. of farmer's	Potential yield (q ha^{-1})	Average Yield (q ha^{-1})		% increase over FP	Extension gap (q ha^{-1})	Technology gap (q ha^{-1})	Technology index (%)
				AWDI	FP				
2021-22	25	25	70.0	63.3	51.7	22.4	11.6	6.70	9.57
2022-23	15	15	70.0	64.7	52.4	23.5	12.3	5.30	7.57
Total/Mean	**40**	**40**	**70.0**	**64.0**	**52.1**	**23.0**	**12.0**	**6.00**	**8.57**

Table 2. Economic analysis of Alternate Wetting and Drying Irrigation (AWDI) and farmer practices of paddy as grown under large-scale cluster demonstration under TN IAMP-IV Thurinjalar sub-basin of Tiruvannamalai District

Year	**Cost of cultivation (Rs./ha)**		**Gross Return (Rs./ha)**		**Net Return (Rs./ha)**		**Benefit Cost Ratio**		**No. of Irrigation (No.)**		**Irrigation water saved (%)**
	AWDI	**FP**	**AWDI**	**FP**	**AWDI**	**FP**	**AWDI**	**FP**	**AWDI**	**FP**	
2021-22	54101	52192	126630	103419	72529	51227	1.34	0.98	21	25	20.0
2022-23	53921	52207	129351	104837	75430	52630	1.40	1.01	20	26	29.4
Average	**54011**	**52200**	**127991**	**104128**	**73980**	**51929**	**1.37**	**1.00**	**20.5**	**25.5**	**24.7**

Fig 1. Assessment of Extension gap and technology gap for grain yield of Rice through AWD irrigation method